



# ANALYSIS AND DESIGN OF THE UNDERGROUND STRUCTURE TO RESIST BLAST LOADS FROM CONVENTIONAL WEAPONS

**C. Sashidhar**

Professor in JNTU College of Engineering, Anantapuramu, India

**M. Nalini**

M. Tech Student in JNTU College of Engineering, Anantapuramu, India

## ABSTRACT

*Conventional weapon is a type of weapon that could be applied to the structure under some considerations. Addressing military ordnance is important not only for the design of military-type protective structures, but also because many improvised explosive devices (IEDs) are produced with either stolen or discarded weapons. In this project, a slab design has been made so that it will resist the conventional weapon, by this we can protect the underground structure from damaging. The structure will be underground where military equipment and the structure will be within the width of the burster slab. Here burster slab will subject to the blast loads.*

**Key words:** Blast Load, Burster Slab, Conventional Weapons, Explosive Devices

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## 1. INTRODUCTION

There are numerous historical examples in which states have used underground facilities in warfare, including the use of underground manufacturing facilities in World War II to conceal and protect valuable industry from destruction. During the war developed an extensive system of underground tunnel for concealing transportation routes, storage facilities, and temporary troop containment areas located their intercontinental ballistic missiles and associated command and control centres in underground sites in order to increase their survivability against nuclear attack. The continuing evolution of underground facilities has provided increasing levels of concealment and protection for a state's critical military components.

The event that has elevated the general level of concern among modern military planners is the prospect that underground facilities are used for the manufacture and storage of weapons of mass destruction.

The result is that the military strategy and operational capabilities for holding hardened and deeply buried targets at risk will be deficient until the appropriate technologies and tactics are developed that will allow to put such targets at risk. One element is training military personnel to perform these missions, which is consistent with the guidance provided by the Special Operations Command that such specialized skills do not "grow overnight." The second issue is to develop the technologies that permit allied forces to detect the presence, depth, layout, and contents of underground facilities, and simultaneously possess the weapons that will allow military forces to destroy or neutralize these facilities. These operational strategies should include the ability to achieve various levels of neutralization, including the ability to disrupt life support functions, create internal environments that are unsuitable for human operations, entomb those facilities, and in the extreme case, completely annihilate these facilities.

Underground structures have features that make their seismic behaviour distinct from most surface structures, most notably 1) their complete enclosure in soil or rock, and 2) their significant length (i.e., tunnels) the design of underground facilities to withstand seismic loading thus has aspects that are very different from the seismic design of surface structures.

## 2. LITERATURE REVIEW

Zeynep Kocaz, Fatih Sutcu & Necdet Torunbalci, Architectural And Structural Design For Blast Resistant Buildings studied the enhancement of building security against the effects of explosives in both architectural and structural design process and the design techniques that should be carried out. Essential techniques for increasing the capacity of a building to provide protection against explosive effects are discussed.

Eric M. Sepp, Lt Col, USAF explained About The Existence Of Deeply Buried Underground Facilities in which he showed how to analyse the underground facilities, locating deeply buried facilities and also how to neutralise it. The concept of neutralisation includes the full range of 'kill' levels that are necessary to accomplish the objectives of the mission.

Youssef. M. A. Hashash, Jeffrey J. Hook, Birger Schmidt, John I-Chiang Yao studied The Seismic Design and Analysis of Underground Structures. Deterministic and probabilistic seismic hazard analysis approaches are required reviewed. The development of appropriate ground motion parameters, including peak accelerations and velocities target response spectra and ground motion time histories are discussed. Joseph L. Giuliani, Daniel J. Hershey, David M. Mc Keown studied on Complex Underground Facilities in which new technology development for the automated generation of underground structures to support correlated visual and constructive simulation.

J. L. Merritt and N. M. Newmark studied The Design of Underground Structures to Resist Nuclear Blast. In this project the experimental results from explosion a set of recommendations for the design of underground structures was prepared.

Einar Broch, Muir Wood Lecture 2010, Tunnels and Underground Works For Hydropower Projects, the paper describes the design of the cost saving unlined high pressure tunnels and shafts.

## BLAST WAVE PHENOMENA

This study examines the nature of deeply buried facility, explores the problems associated with detecting these sites, and focuses on unconventional approaches for defeating these targets. In this the structure is to be designed for the following two conditions:

1. Dynamic Analysis for blast loads.
2. Static Analysis for normal loads.

### Dynamic Analysis for Blast Loads

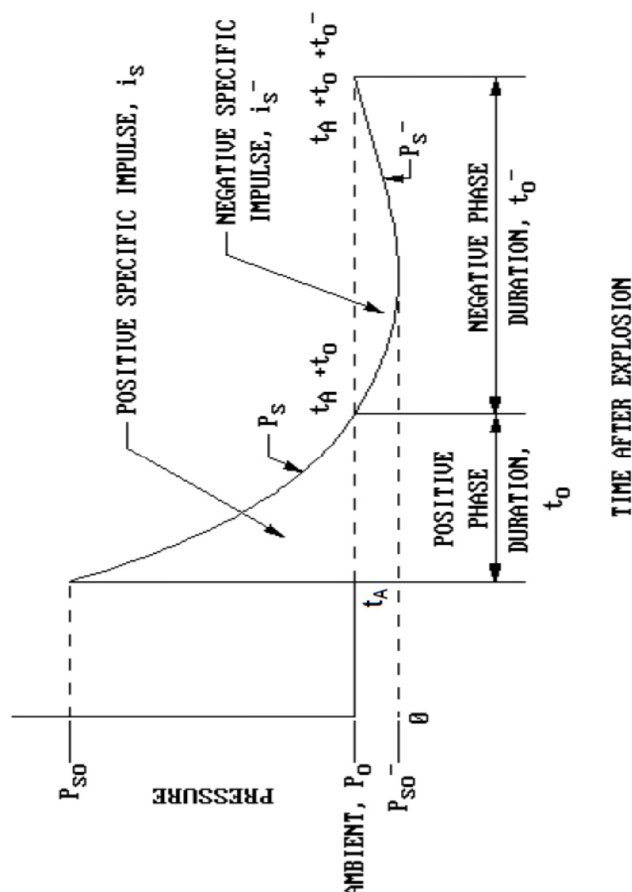
- Guidelines given in UFC are followed for the dynamic design of the structural elements using ultimate load theory.
- ANSYS analysis is carried to simulate the weapon effects and to assess the stress in various elements of the structure.

### Static Analysis for Normal Loads

- Limit state method as per IS: 456 are used for designing the elements of the structure for normal loads. Earth quake loads will not govern the design, since the blast loads are much severe than Seismic Loads.

### BLAST-WAVE PHENOMENA

The violent release of energy from a detonation converts the explosive material into a very high pressure gas at very high temperatures. A pressure front associated with the high pressure gas propagates radially into the surrounding atmosphere as a strong shock wave, driven and supported by the hot gases. The shock front, termed the blast wave, is characterized by an almost instantaneous rise from ambient pressure to a peak incident pressure  $P_{so}$  (Figure-1).



**Figure 1** Free-Field Pressure-Time Variation

### 3. CHARACTERISTICS OF EXPLOSIVE PROCESSES, DEVICES, AND ENVIRONMENTS

**NUCLEAR WEAPONS:** The principles of modern nuclear weapons are similar to those of the first nuclear devices. Once a critical mass of a nuclear material (such as uranium or plutonium) is achieved, the chain reaction will result in the release of thermal, radioactive, and other energies that will create a nuclear environment.

The weapons are complicated, but should be viewed as sources for vast amounts of energy that, when released, will create the effects that must be resisted by protective systems.

#### CONVENTIONAL WEAPONS

This section is a general summary of conventional weapons (CW). For information on accidental explosions, consult other sources. The designer or analyst must have reasonable assessments on the type of weapon systems that could be applied to the structure under consideration. Addressing military ordnance is important not only for the design of military-type protective structures, but also because many improvised explosive devices (IEDs) are produced with either stolen or discarded weapons. Typical military devices are introduced first, and explosion processes and phenomena are treated, as the foundation for defining physical threat environments.

**Table 1** Characteristics of Typical Generic High-Explosive Bombs

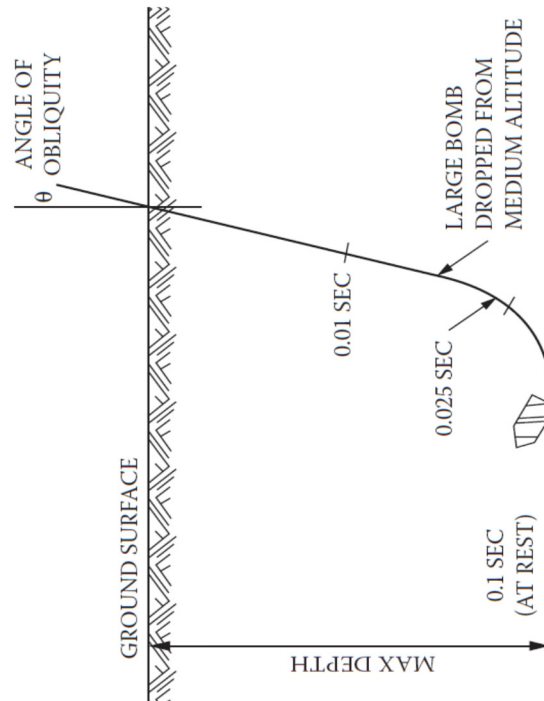
Designation	Classification	Total Weight	Diameter (in)	Length L (in)	Charge Weight	Slenderness ratio	Sectional Pressure
		Wt (lb)			Ratio %	L/d	4W/d' (pp psi)
GP	100	110	8	29	51	3.6	2.2
GP	250	260	11	36	48	3.3	2.7
GP*	250	280	9	75	35	8.3	4.4
GP	500	520	14	45	51	3.2	3.4
GP*	500	550	11	90	35	8.2	5.8
GP	750	830	16	85	44	5.3	4.1
GP	1000	1020	19	53	54	2.8	3.6
GP*	1000	1000	14	120	42	8.6	6.5
GP	2000	2090	23	70	53	3	5
GP*	2000	2000	18	150	48	8.3	7.9
GP*	3000	3000	24	180	63	7.5	6.6
SAP	500	510	12	49	30	3.9	4.5
SAP	1000	1000	15	57	31	3.8	5.6
SAP	2000	2040	19	66	27	3.5	7.2
AP	1000	1080	12	58	5	4.8	9.5
Ap	1600	1590	14	67	15	4.8	10.3

\* High slenderness ratio bombs

**Penetration:** Penetration paths of bombs into earth have J shapes, as shown in Figure-2.

The straight part is approximately 2/3 of the total length, and the curvature radius is about 1/5 to 1/3 of the total path length. Figure-8 can be used to estimate penetration depths.

Most standard bombs have slenderness ratios (length to diameter) of 3 to 6; they are terra dynamically unstable and produce J-shaped penetration paths.

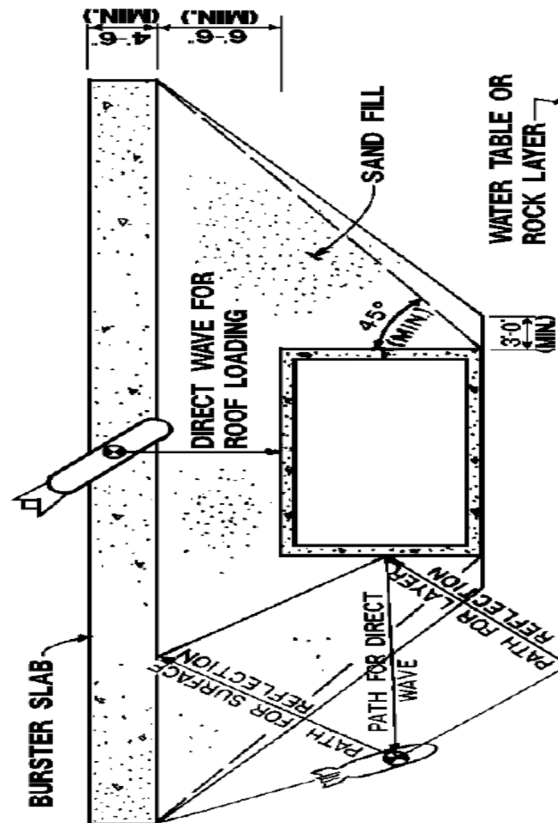


**Figure 2** Courses of bombs that from J-shaped paths in earth

#### 4. DESIGN OF BURSTER SLAB

For protective structures, a burster slab prevents a weapon from penetrating through the soil and detonating adjacent to the structure. Its thickness and length may have to be determined by a trial and error procedure in order to limit pressures on the structure to a given value.

The minimum reinforcement is 0.1 percent in each face, in each direction or a total of 0.4 percent. In the design of structures subject to accidental explosions, the ground floor slab of the donor building serves a purpose similar to that of a burster slab. The floor slab helps to prevent fragment penetration and to attenuate the load.



**Figure 3** Geometry of a buried structure

Provide minimum steel as per UFC.

The minimum reinforcement is 0.1% in each face, in each direction or a total surface of 0.4%.

Thickness of burster slab considered,

$D = 2500\text{mm}$  (from load roof)

$pH = 0.1$

$A_{sh} = 10 \times (pH) \times D$

$= 10 \times 0.1 \times 2500$

$= 2500 \frac{\text{mm}^2}{\text{m}}$

$\therefore$  Diameter of the bar = 20mm

Spacing of the bars (Top and Bottom)

$= 120\text{mm}$

$pV = 0.1$

$A_{sv} = 10 \times pV \times D$

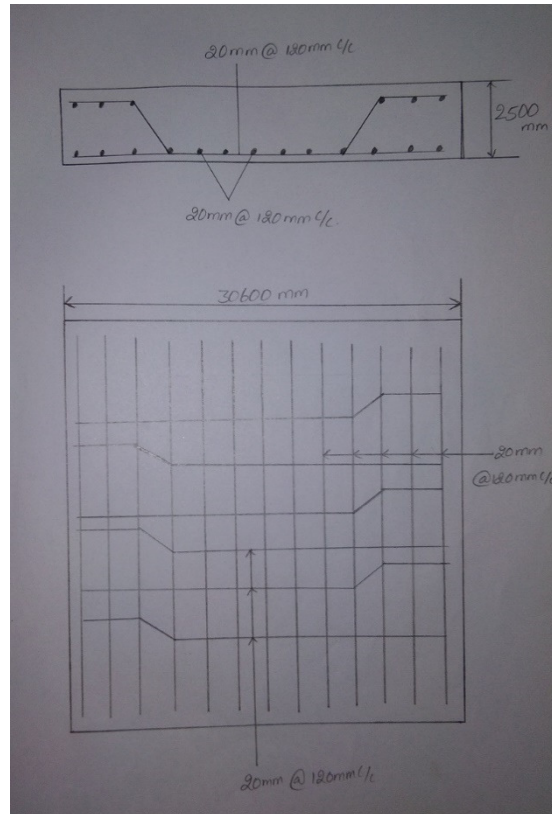
$= 10 \times 0.1 \times 2500$

$= 2500 \frac{\text{mm}^2}{\text{m}}$

$\therefore$  Diameter of the bar = 20mm

Spacing of the bars (Top and Bottom)

$= 120\text{mm}$ .



Reinforcement Details of Burster Slab

## 5. CONCLUSIONS

The burster slab prevents a weapon from penetrating through the soil and detonating adjacent to the structure. A burster slab is not mandatory, but if it is not used the structure will have to be buried much deeper.

The burster slab must extend far enough beyond the edge of the building to form at least a 45 degree angle with the bottom edge of the building. It may have to be extended further, though, if it is possible for a bomb to penetrate at a very shallow angle, travel beneath the burster slab and detonate adjacent to the structure.

Sand is used as backfill because materials with high volume of air-filled voids and low relative densities are poor transmitters of ground shock. In addition, sand resists penetration better than soil.

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